Analysis of puddles in Swamp areas of Banyuasin District using the image Lands at 8 by NDWI method

by Indrayani Indrayani

Analysis of Puddles in Swamp Areas of Banyuasin District Using the Image Landsat 8 by NDWI Method

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Abstract

Stagnant water and flooding in a region generate the disruption of activities from the area use. The swamp area is one of the areas that always flooded in which nowadays the development in the swamp area is more massive done, so that required road infrastructure to support regional development. The road construction planning needs to take attention to the areas of inundation exist in the swampy areas so that the road can be built by the basic function of the swamp. The use of remote sensing technology is an economic alternative that can be used in the introduction of the puddels. In this study, the classification of puddles will be done using the Landsat 8 image with the Normalized Different Wetness Index (NDWI) method by using the combination on band composite 53. The results shows that the classification by obtaining the range of reflectance value in which (-0,7851) – (-0,404`) for non-water body, (-0,4041) – (-0,2021) for low puddles, (-0,2021) – 0,0733 for medium puddles, 0,0733 – 0,1057 for high puddles, and 0,1057 – 0,8726 for rivers.

Keywords: Stagnant water, Puddles, Swamp, NDWI, Remote Sensing

Introduction

The development of areas for infrastructure development is constrained by vulnerability to water, wind, erosion, stagnant water, and flooding. Stagnant water and flooding affect the carrying capacity of the land due to giving the existing physical condition. It can be seen that the flatter a region in topography and the closer to the sea, the more likely to be the occurrence of puddles and floods. The considerations of topography in swamp areas are not based on the slope and altitude on the soil surface because most of the swamp areas are flat areas (Indrayani, et al, 2016). The stagnant water and flooding generate the problem in the activities of land use (Sukarman *et al*., 2013). The swamp area is one of the areas that always flooded in which nowadays the development in the swamp area is more massive done due to the decreasing of productive area. In addition, the government develops the swamp area in several sectors such as agriculture, plantation, and fishery (Suriadikarta dan Sutriadi, 2007; Arsyad *et al*., 2014). The swamp area becomes one of the alternatives in the development of road infrastructure. However, the existence of the road infrastructure should take in attention especially in the environmental aspects because the engineering should retain the role and function of wetland ecosystem without reducing the function and benefits of the road network system to be built in the swamp area (Harry, 2007; Suryoto *et al*., 2017).

The location of inundation in a region can be known through immediate analysis to the studied area. However, the direct measurement requires a high cost. Remote sensing is one method that can be used to illustrate the puddles using Landsat with the approach of specific bands (Huang *et al*., 2014; Xia *et al*., 2017).

Nowdays, Landsat program has released the Landsat 8 in remote sensing technology that has sensor of Onboard Operational Land Imager (OLI) sensor and Thermal Infrared Sensor (TIRS) which has 11 channel number consisting of 9 channels (bands 1-9) residing on OLI and 2 channels (band 10 and 11) on TIRS (Lapan, 2015). Geographic Information System (GIS) using remote sensing technology is one of the economic alternatives in the determination of potential land cover (Karakus *et al*., 2015; Wondrade *et al*., 2014). Some methods used in interpreting the image using wavelength are NDVI (Normalized Different Vegetation Index), NDWI (Normalized Different Wetness Index), and NDSI (Normalized Different Soil Index) (Gandhi *et al*., 2015; Deng *et al*., 2015; Haikal, 2014). NDWI is remote sensing technology based on the sensitivity indicator to changes in leaf water content (Haikal, 2014). The result of puddles classification is a thematic map of puddles height that used as the initial stage of road planning determination guideline in the swamp area.

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Materials and Methods

Study Area

The research was conducted at swamp area in Banyuasin regency which has the wide area of 1,183,299 Ha or approximately 12.18% of total area of South Sumatera Province. It is located in the coordinates between 1° 37′32.12″ to 3° 09′15.03″LS and 104° 02′21.79″ to 105° 33′38.5″BT. Banyuasin regency consists of 80% wet lowland with slope 0 – 8% of 1,181,610 Ha and 8 – 15% of 1,689 Ha (Kabupaten Banyuasin, 2011). The study area can be seen in Fig. 1.

Classification Method

To obtain the thematic map of the puddles classification, it is done by using the remote sensing technology through Landsat 8 image interpretation which is downloaded from the United States Geological Survey on the scene: path 124/row 062.

The stages of data processing including: (1) pre-processing stage (giving the limit space of image that serves to the area of research and reduce the size of image files as well as geometric and radiometric correction); (2) stages of data processing (color composite, digital image interpretation for sharpening, smoothing filter, contrast, and multispectral classification in Landsat 8 image, and NDWI transformation); and (3) the field test stage to check the truth of the classification result using GPS navigation tool.

The inundation classification was carried out using *Normalized Different Water Index* (NDWI) method combining band 3 and band 5 in detecting the inundation that occurred. Visible channels on Landsat 8 (band 1-4 OLI) at the time of flood will increase the value of reflectance whereas the infrared channel (NIR, SWIR, MIR) will be decreased. The transformation of NDWI can use the equation below.

$$NDWI = (Band\ 3 - Band\ 5)/(Band\ 3 + Band\ 5)$$

The characteristics of OLI sensor on satellite Landsat 8 has 9 bands which shown table 1 below.

Table 1. The characteristics of OLI sensor on satellite Landsat 8

Band	Wavelength (μm)
Band 1 (Coastal aerosol)	0.433 – 0.453
Band 2 (Blue)	0.450 – 0.515
Band 3 (Green)	0.525 – 0.600
Band 4 (Red)	0.630 – 0.680
Band 5 (NIR)	0.845 – 0.885
Band 6 (SWIR 1)	1.560 – 1.660
Band 7 (SWIR 2)	2.100 – 2.300
Band 8 (Panchromatic)	0.500 – 0.680
Band 9 (Cirrus)	1.360 – 1.390

(Lapan, 2015).

Results

Classification of the puddless based on spectral values

The interpretation of the puddles will be analyzed based on NDWI value with the combination of 3 bands of green spectrum (visible) at 0.525-0.600 μm. The land surface object will have varied spectral responses when the land is inundated or not inundated. At the flood, there will be an increase in visible band (1 – 4 OLI) whereas the infrared band (NIR, SWIR) will be decreased.

To conduct the interpretation of the puddles in the study area, the analysis of Landsat 8 image which taken in December was used. These results represent the data in the rainy season. The sampling point to determine the puddles were drawn using a 53 band composite that represents the aquatic and non-aquatic regions. Using 53 band combination, it would be distinguished by aquatic and non-aquatic areas. Because at the wavelength of 0.4 – 0.5 μm, the water will be high and tend to decrease until it disappears in the NIR spectral range with a wavelength of 0.8 μm upwards. The sample points which taken to determine the average reflectance value for the non-aquatic area are seen in fig. 2.

Fig.2 shows the average reflectance value in band 3 (green) and band 5 (NIR). The value distinguishes non-aquatic and aquatic regions for low, medium, high, and rare interior ponds.

Fig. 3 represents the spectrum of band 3 (green) with wavelength 0.525 – 0.600 μm in which shows the high reflectance value at the puddles. The area has 0,1044 and 0.0512 as the highest and the lowest reflectance value, respectively. In the other hand, the NIR spectrum in band 5 with wavelength 0.845 – 0.885 μm shows the high reflectance value in no-aquatic regions which is 0.3102 μm and the reflectance value will continue to decrease in the puddles that shows 0.0480 μm.

The NDWI value shows the difference between the NIR and the visible band. The higher the value of the NIR difference in band 5 and band 3, the NDWI value will be smaller and vice versa. The NDWI value can be seen in Fig. 2.

The NDWI value with a combination of band 3 (visible) and band 5 (NIR) will show the positive value to the puddles. The NDWI will show the higher value if the area has the high degrees of wetness and vice versa. Furthermore, The NDWI classification is divided into 5 classes which shown in Table 2, and the results of the classification of puddles based on the reflectance value can be seen in Fig. 3.

Table 2. The NDWI classification .

Class	Reflectance value
Not a water body	(- 0.7851) – (- 0.4041)
Low Puddles	(- 0.4041) – (- 0.2021)
Medium Puddles	(- 0.2021) – 0.0733
High Puddles	0.0733 – 0.1057
River	0.1057 – 0.8726

The accuracy in the interpreting of the puddles was carried out using a confusion matrix. The confusion matrix will match the data of inundation classification with the result data of field cross check conducted by direct observation. In addition, the field cross-check also supported by the supporting secondary data, interview, etc.

Puddles accuracy test

The survey was conducted from February to April 2017 at several subdistricts such as Talang kelapa, Tanjung lago, Muara telang, Rambutan, and Banyuasin I. The description of the puddle at the sampling point can be seen in Fig. 4.

Table 3 shows the level of accuracy of the result of puddle height classification using Landsat 8 with NDWI method. The results show that the percentages of the overall rate are 91.77% which indicate that the result of puddle classification can be used in the generating of the water level thematic maps based on the height of the ground surface.

The height of puddles was also obtained from the interviews with several sources including staff and secretary of subdistricts government in Talang kelapa subdistrict, Kenten laut, Rambutan, Banyuasin I, and staff of the regional disaster management agency office of South Sumatera Province, Head of agency and employees of the regional disaster management agency in Banyuasin regency, as well as residents around the study area.

The classification of water level to the height of the soil is classified into 3, i.e. (1) the height of 0-20 cm means that the stagnant water floods the rice fields and the swamp areas. (2) The height of 20 – 50 cm means stagnant water inundated rice fields, swamps, and access roads; (3) > 50 cm means that the stagnant water inundated rice fields, swamps, access roads, and settlement.

Discussion

Band 5 and band 3 could be used to determine the puddles. The reflection on the puddle will be affected by the water base material or the material covered by the puddle. The absorption characteristics will be influenced by the type, size, and type of material which present in the puddles. In the other hand, the water depth will be distinguished from the level of color brightness in the water area. The darker the color of the puddle will show the greater the water depth and the bright color indicates the lower water depth. Water with a high depth will absorb more wavelength so that the reflect the spectral value will be lower compared to the low depth.

Du *et al*. (2014) have evaluated the potential of Landsat-8 OLI image for land surface water mapping (LSWM) in the Yangtze Basin and Huaihe River Basin, China. The results showed that OLI image could be used accurately and easily for LSWM. Furthermore, Xu (2006) have used NDWI with mid-infrared bands such as Landsat TM ribbon 5 for near-infrared bands used in the modified NDWI (MNDWI) and reported that the MNDWI could enhance the open water feature while efficiently pressing and removing built-up ground noise as well as soil and vegetation noise. Enhanced water information using NDWI is often mixed with built-up land noise, and the extracted water area is too high. Thus, MNDWI is better suited for improving and extracting water information for aquatic area against a background dominated by areas of built land because of its advantages in reducing and even removing land noise from NDWI.

Some considerations in determining road trace as the initial stage of road planning in the swamp area based on topography and hydrology condition are topography condition commonly used in deciding road trace. However, the land altitude or slope can not be applied in deciding road trace in swamp area since the swamp area has relatively flat area altitude. Furthermore, the swamp area usually flooded so that the topography factor must always be considered together with the hydrological factor by considering water level to ground level.

Conclusion

The classification of the puddles obtains a range of reflectance values of (-0.7851) – (-0.4041) for non-aquatic regions, (-0.4041) – (-0.2021) for low puddle areas, (-0.2021) – 0.0733 for medium puddles with dengan the height 20-50 cm (0.0733 – 0.1057) for high puddles, and (0.1057 – 0.8726) for river. In general, Banyuasin has the low inundation level and only few areas have high puddle areas.

Acknowledgements

Acknowledgements for : (i) Ministry of Research, Technology and Higher Education of the Republic of Indonesia; (ii) State Polytechnic of Sriwijaya.

Table 3. Confusion Matrix on Puddles Classification

Description		Reference Data (Field Data)		Sum	*Accuracy's User* (%)
		Puddles	Non Puddles		
Classification Data	Puddles	58	7	65	89.23
	Non Puddles	6	87	93	93.55
Sum		64	94	158	
Accuracy's Producer (%)		90.63	92.55		91.77

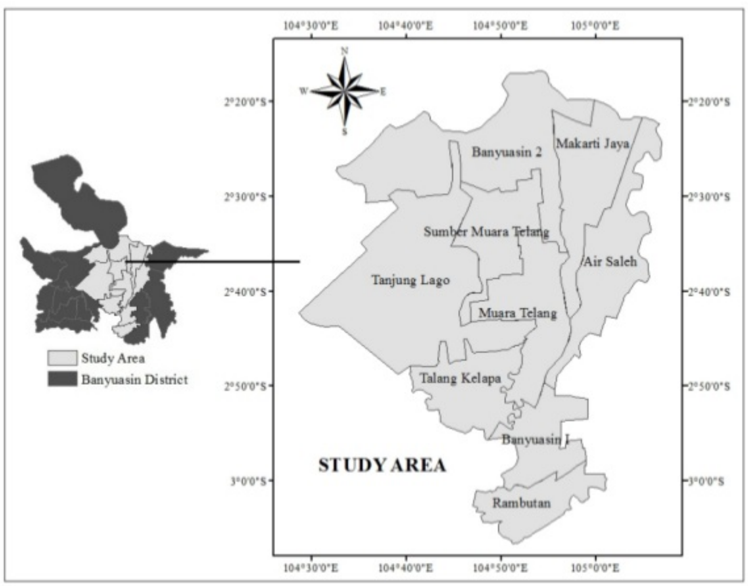
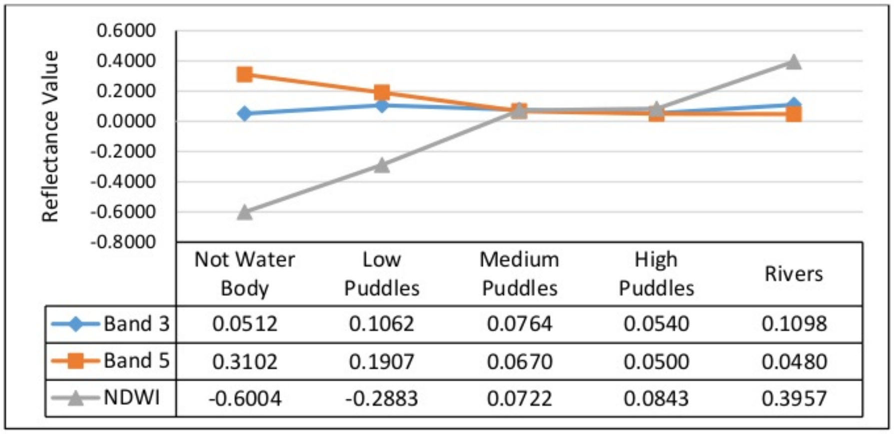
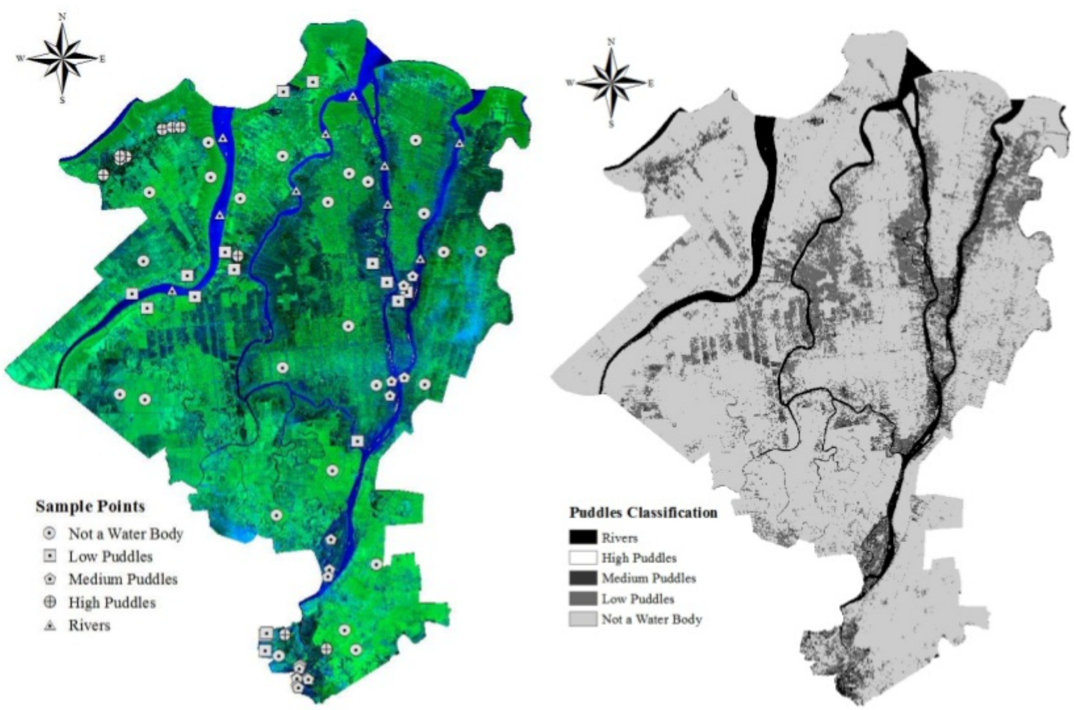


Fig. 1. Study Area



	Not Water Body	Low Puddles	Medium Puddles	High Puddles	Rivers
Band 3	0.0512	0.1062	0.0764	0.0540	0.1098
Band 5	0.3102	0.1907	0.0670	0.0500	0.0480
NDWI	-0.6004	-0.2883	0.0722	0.0843	0.3957

Fig. 2. The reflectance values of Band 3 *(Green)*, Band 5 (NIR) and NDWI.



(a) (b)

Fig. 3. Puddles identification on the composite band 53. (a) sample point of determination based on reflectance value, (b) classification result of the puddles.

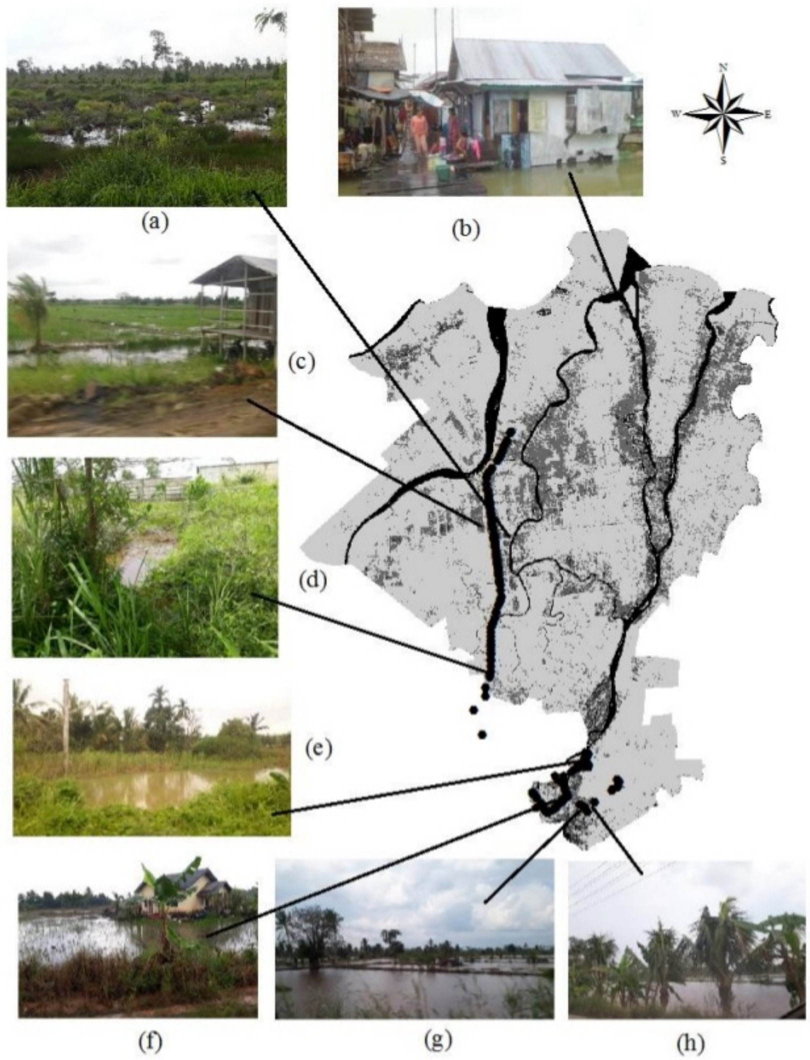


Fig. 4. *Cross* Check of the result of puddles, (a) the swamp area in Tanjung Lago subdistrict; (b) the inundation in Sungsang Banyuasin II; (c) The puddle in paddy field of Tanjung Lago subdistrict; (d) The swamp area in Talang Kelapa subdistrict; (e) The puddle area in Banyuasin I; (f) The puddle area in the settlement of Rambutan subdistrict; (g) The puddle in paddy field of Rambutan subdistrict; (h) the puddle in paddy field of Sungai Dua.

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